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AUTHOR Jacobs, John W.; And Others
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ABSTRACT

The purpose of this paper is to present a computer-based attention reduction training (ART) model and to outline important issues that must be addressed before the model can be incorporated into an educational setting. The model is based on the dual task technique, an assessment procedure developed by memory researchers. Methodological assumptions underlying the technique and issues concerning the use of the term "automaticity" in reference to the results of such training procedures are discussed, and an overview of problems pertaining to terms used to communicate training outcomes related to transfer is presented. Vertical transfer, an aspect of transfer with potential for guiding research in training and instructional design, is defined and subsequently used in describing the ART model. A detailed description of computer-based ART procedures that incorporate electronic symbols as electronics training material is provided, and empirical issues related to this model and its application to educational settings are addressed. Diagrams of task performance patterns and electrical schematics are appended. A list of 48 references is included. (MES)

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Authors:

John W. Jacobs
John V. Dempsey
David F. Salisbury

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Implications of an Attention Reduction Training (ART) Model for Education and Technology

John W. Jacobs
Department of Psychology

John V. Dempsey
Center for Educational Technology

and

David F. Salisbury
Department of Educational Research

Florida State University
Tallahassee, Florida 32306

Paper presented as part of the Fourth Annual Open Forum on the Foundational Issues of the Field (Research and Theory Division) at the annual meeting of the Association for Educational and Communications Technology, February 25 - March 1, 1987.

Running Head: ATTENTION REDUCTION TRAINING

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Abstract

Recent research in automaticity training suggests that attentional resources related to certain intellectual skills can be engineered and this type training facilitates later transfer of learning. One potentially useful attention reduction training technique involves requiring learners to respond to two tasks simultaneously. Since primary task variables can be manipulated with concomitant increases or decreases in secondary task (i.e., the task of interest) performance, it is suggested that automaticity be viewed as being continuous rather than discrete in nature. The technology for applying this dual task technique to electronics training is discussed. The basic procedure involves training an underlying (subordinate) skill of recognizing several common electrical components (e.g., resistor, battery, diode, etc.) in order to investigate subsequent learning on a superordinate task (i.e., recognizing simple circuits within larger schematic configurations). It is pointed out that several training issues need to be empirically tested before the feasibility of attention reduction training (ART) using the dual task procedure can be judged useful for educational applications.

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Introduction

The purpose of this paper is to present a computer-based attention reduction model of training and outline important issues that must be addressed before the model can be incorporated into an educational setting. The rationale for developing this model comes from current research and theory related to metacognition; specifically, aspects of metacognition related to executive control activities such as planning, checking, and monitoring. As a result of these activities, the executive controller is hypothesized to regulate and orchestrate other, subordinate mental processes (see e.g., Wagner & Sternberg, in press). In theory, executive control activities interact with and compete for attentional space with these subordinate processes (Brown & Campione, 1979). Thus, training aimed at decreasing attentional capacity related to performance of one or more relevant subordinate processes may serve to increase attentional resources for (superordinate) executive processes.

Our model of attention reduction training (ART) is based on an assessment procedure developed by researchers in the area of memory (see e.g., Britton, Piha, Davis, & Wehausen, 1978; Eysenck & Eysenck, 1979; Tyler, Hertel, McCallum, & Ellis, 1979). This procedure is referred to as the dual task technique. The dual task technique involves having subjects respond to two tasks simultaneously. This task, as originally employed, was used to assess the amount of attentional resources consumed when performing memory-related tasks, such as semantic verses structural encoding of verbal stimuli. Subsequent research has, in some cases, not supported the use of this task as a valid assessment tool in this way due to incomplete or inaccurate accounting of methodological assumptions thought to underlie the dual task technique (see e.g., Fisk, Derrick, & Schneider, 1982). These assumptions will be described in detail in the next section. Despite these potential problems, we believe that this assessment tool may be a potential alternative as a training device, given that (a) both tasks are computer-based, thus allowing close and accurate monitoring of critical performance components of each task, and (b) an independent assessment of automatic processing be employed. One such measure is vocalization latency, which is currently being used for studying automatic processing of critical prerequisite skills in reading (e.g., Stanovich, Cunningham, & Feeman, 1984a, 1984b; see also Cohen, 1987 for a review of automatic processing measures used in reading).

The idea that task components may be trained to an automatic level has been the focus of increasing interest over the past several years. One training procedure that has proven effective for producing automatic processing was developed by Schneider and Shiffrin (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977) and is referred to as the constant mapping training procedure. These researchers have provided evidence that extensive practice (often over thousands of trails) using this procedure results in automatic processing of skill components, supposedly due to the reduction of attentional resources needed for performing these requisite components. It may be more parsimonious to say that such training may result in increased fluency, a term that denotes the

combination of speed and accuracy, rather than reduced attention or automatic processing of skill components. Regardless of the nature of performance gains (e.g., fluency, automaticity, or reduced attentional resources), the idea that certain types of training may positively influence transfer, above and beyond traditional mastery level training, is both intriguing and may prove beneficial to many areas of training and education.

A conceptual framework for describing and testing aspects of the ART model is Gagne' and Briggs' (1979) learning hierarchy. A training outcome that is closely related to this model involves the transfer of lower-order (subordinate) skills to higher-order (superordinate) skills. This particular view of transfer is referred to as vertical transfer (Gagne', 1965).

The following sections of this paper will describe the dual task technique as well as briefly discuss issues concerning the use of the term "automaticity" in reference to results of such training procedures. Next, an overview of problems pertaining to terms used to communicate training outcomes related to transfer will be given. One particular aspect of transfer that we feel has potential for guiding research in the areas of training and instructional design, referred to as vertical transfer, will be described and subsequently used when describing the ART model. Following this, a detailed description of computer-based ART procedures that incorporate electronic symbols as training material will be presented. Finally, empirical issues related to this model and its application to educational settings will be addressed.

Implications of Automaticity Training for the ART Model

Historically, theorists have postulated at least two separate aspects of attention: mental activities that require a minimum of attention, referred to as automatic processes (Posner & Snyder, 1975; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977) and mental activities that require increased amounts of attentional capacity. The latter type of mental processes have been referred to as conscious (Posner & Snyder, 1975), controlled (Schneider & Shiffrin, 1977), and effortful (Hasher & Zacks, 1979). We will use the term effortful for the sake of clarity. The idea of variable attentional capacity is based on a model of human information processing that assumes that the total amount of attentional capacity is limited (e.g., Kahneman, 1973). Kahneman's model also postulates that attentional limitations interact with processing demands at any point in the information-processing sequence (between encoding and responding) and that attentional requirements necessarily increase as processing nears the response end of the system (see also Posner & Keele, 1970). Thus, Kahneman's (1973) "variable capacity" model differs from other "bottleneck" models in that it doesn't hypothesize a specific processing stage where selective attention is thought to operate (see e.g., Broadbent, 1958; Keele, 1973; Norman, 1968).

In their article, Posner and Snyder (1975) listed several criteria for defining automatic processes including the following: automatic processes (a) may occur without intention, (b) do not necessarily give rise to awareness, (c) tend to interfere minimally

with other cognitive processes. In a subsequent article, Hasher and Zacks (1979) expanded these criteria to include three additional characteristics based on a developmental framework. These characteristics were that once the components of a skill reached the automatic level, they (d) showed little improvement with age, (e) did not improve with continued practice, and (f) were relatively unaffected by differences in motivation, education, early experience, culture, and intelligence. In contrast, processes at the effortful end of the information processing continuum (a) interfere with the ability to perform other effortful tasks, (b) are most always available to consciousness, (c) are used voluntarily, and (d) tend to improve with practice (Posner & Snyder, 1975).

Researchers in cognitive psychology have extended this view of differential capacity requirements for mental activities and have argued that complex operations can, with extensive practice, occur with a minimum amount of attention allotted to them (Posner & Snyder, 1975; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). One technique found to facilitate automatic mental processing is referred to as the constant mapping technique (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). The constant mapping technique involves having subjects respond to a single stimuli or fixed set of stimulus items in the same way across numerous trials. Critical components of this technique will be described in the next section. Important to this discussion is a feature related to the nature of performance change as a function of constant mapping practice; namely, the reduction of attentional resources. This change was documented by Shiffrin and Schneider (1977). These researchers reported that after approximately 2100 trials, subjects were able to discriminate between two different sets of letters (same category condition) as fast as when they were required to discriminate between numbers and letters (different category condition). As a result of training, time to accurately respond in the same category condition was reduced from approximately 400 mseconds to 80 mseconds. This result was taken as evidence that processes can become automatic with sufficient practice using the constant mapping procedure and that the nature of skill components changes as it reaches the automatic level. That is, automatized skills do not require as much attention as evidenced by a dramatic decrease in reaction time performance. In addition, a dual task assessment procedure was used to verify reduction of attentional resources needed to perform the secondary task. That is, the secondary task (the skill of interest) was no longer affected by the number of processes being performed simultaneously.

Another study performed by Spelke, Hirst, and Neisser (1976) provided evidence that subjects could perform other dual tasks simultaneously and that subjects' performance levels change dramatically as a result of extensive practice. In this study, subjects were required to read silently and to simultaneously copy words dictated to them by the experimenter. Though very difficult at first, subjects were able to read while copying dictation as well as they had been able to read previous to the experiment. This result was taken as evidence that the skill of copying dictation had become automatic for the subjects, due to the fact

that it did not interfere with their reading.

In the area of reading, recent theory and research has suggested that by automatizing critical prerequisite reading skills (e.g., letter recognition and word recognition) the reader can increase higher-level comprehension skills. For example, a theory of automatic information processing proposed by Laberge and Samuels (1974) has guided much of the research in this area. Their theory describes several stages involved in transforming written stimuli into meaning. A major facet of the theory is that there exists a limited-capacity attentional mechanism at each of the stages and that well-learned (i.e., automatized) stimuli may be processed and/or activated independent of attention at various levels of the system.

There is growing empirical evidence lending support to critical aspects of Laberge & Samuels (1974) theory. At the subword level, Staller and Sekuler (1975) report that letter naming speed of above average readers to be faster than for below average readers. At the word level, several articles have noted that oral reading speed of words is highly correlated with reading ability as measured by various standardized reading batteries. For example, Stanovich, Cunningham and Feeman (1984a) found that decoding speed of third and fifth graders, measured by subjects' vocalization latencies to words and psuedowords, was highly correlated to standardized reading test performance (see also Deno, Mirkin, & Chiang, 1982; Perfetti & Hogaboam, 1975; Stanovich et al., 1984b). In addition, at least two studies have presented results indicating that a causal relationship exists between automatic processing of individual words and performance on standardized reading tests (Lesgold & Resnick, 1982; Lomax, 1982). For example, Lesgold and Resnick (1982), using a causal modeling technique, presented evidence suggesting that a strong causal (nonreciprocal) path exists from word vocalization latency measures to reading comprehension.

It is apparent from the reading literature presented above that researchers in this area believe that automatic skill development of prerequisite reading skills can be measured by word vocalization latency measures. This observation has been noted in a recent review of this literature by Cohen (1987). However, to our knowledge, no empirical studies have investigated the possible relationship between word vocalization latency measures and attentional capacity. One way to study this is by comparing results of training using the secondary task technique with speeded measures. This possibility is explored in more detail in the next section.

Dual task paradigm methodology

As an assessment tool, the dual task relies on the following three assumptions: (1) both the primary and secondary tasks share a common pool of attentional resources, (2) primary task performance remains constant relative to when processing is independent of any competing tasks, and (3) primary task components don't become automatized with practice (Fisk et al., 1982). To satisfy the first assumption, it must be demonstrated that performance on one task necessarily decrease in the presence of the other, time-

shared task. Since the competing (time-shared) task must consume a constant amount of attentional resources (assumption 2), it is usually labeled the primary task; that is, the task of primary importance for the subject. The fact that the subject performs the primary task at a level equal to when it is processed independent of any competing task allows one to infer that performance decrements related to the secondary task result from reduction of available attentional resources (when performing both tasks simultaneously).

The final assumption is particularly relevant to the ART model. Specifically, if both tasks being performed simultaneously are maintained over time or if independent trials in which they are performed are repeated, then one must consider the effects of this practice. That is, in order for the conditions set up by the first two assumptions to be maintained when dual tasks are practiced, evidence must be given indicating that the attentional resources related to the primary task have not attenuated. In their articles, Schneider and Shiffrin present evidence that use of a varied mapping practice procedure ensures that attentional resources won't decrease due to extended amounts of practice. Briefly, varied mapping practice involves having subjects vary their responses to a given stimulus item across trials.

In sum, the three assumptions just described allow one to describe decreases in secondary task performance as being a product of allocation of attentional resources to the primary task when using the dual task paradigm. By employing a dual task paradigm where the primary task responding conforms to a varied mapping practice procedure and secondary task responding conforms to a constant mapping practice procedure, a training procedure may be established that serves to reduce attentional resources related to the secondary task. Moreover, according to the current view of automaticity, if attentional resources used when performing a skill are reduced to a minimum (i.e., they don't interfere with other effortful processes), then they are thought to be automatic in nature. Within the context of the dual task paradigm, this would occur when performance of the secondary task becomes equal to pretraining (independent processing) levels. This event is presented graphically in Figure 1.

Insert Figure 1 about here

According to the scenario above, automaticity may be viewed as a continuous rather than a discrete phenomenon since the primary task may vary in complexity or difficulty. Thus, use of a simple primary task (e.g., reaction time to the presence or absence of a specified stimuli) would result in a level of automatic processing of secondary task components that is not equal to similar results using a more complex primary task (e.g., a decision making task involving instances of words and non-words). Our conception of dual task training incorporates varying primary task workload, which is designed to foster increased reduction of secondary task attentional resources. Workload is defined as the amount of attentional resources required to perform a specified task and can

be assessed by measuring performance decrements of the secondary task (in terms of both accuracy and response latency).

Due to what we believe to be the continuous nature of automaticity and automatic processing, we prefer to call the result of training using the dual task paradigm attention reduction rather than automaticity. However, due to inherent problems involved in the sole use of secondary task performance measures to assess "automatic" skill processing as well as our idea of task "workload", we suggest that at least one other independent assessment tool be used.

Literature in the reading area offers several suggestions for assessing automatic skill processing in reading. For example, use of vocalization latencies has been suggested (e.g., Lesgold & Resnick, 1982). That is, present subjects with critical words, symbols, or concepts etc. and measure the latency for verbally identifying these stimuli. Once identified, these latencies can then be directly compared to the vocalization latencies of other, presumably automatically processed stimuli, such as digits or colors. The Stroop task (Stroop, 1935) has also been used for assessing automatic processing of words (see e.g., Stanovich, Cunningham, & West, 1981). However, use of this task in this way has been criticized (Cohen, 1987).

Issues Involving Communication of Training Outcomes Related to Transfer Effects

Two primary outcomes of training are maintenance and transfer (generalization). These terms refer to continued appropriate performance over time and across tasks and/or settings, respectively. The term transfer will be used throughout the remainder of this paper in reference to the combined concepts.

This discussion of transfer reviews several traditional distinctions used to describe transfer effects outlined by Royer (1979). It is our view that most traditional, descriptive labels used to communicate training outcomes related to transfer may confuse rather than enlighten. Of particular concern is the use of such terms as near and far when attempting to describe the extent or level of transfer effects. There is one aspect of transfer described by Royer (1979), referred to as vertical transfer by Gagne' (1965, 1985), that we feel has potential for guiding and evaluating future research within the area of education and instructional design. This aspect of transfer will be discussed in detail and will subsequently be used as a basis for describing an attention reduction model of training that may influence learning outcomes above and beyond traditional mastery training alone.

Traditional distinctions describing transfer effects

Several recent articles have focused on the theoretical aspects of transfer of training as well as skills thought to facilitate such transfer. For example, Royer (1979) described four conceptual distinctions that have traditionally been used to define transfer of training effects. Each distinction compares two seemingly dichotomous relations. One distinction that has been made involves specific and nonspecific transfer. Specific transfer

describes a condition where the original and new (transferred) learning situations share common stimulus elements. For example, two different experimenters may teach the same skill (e.g., sharing) in the same (lab) setting. In contrast, nonspecific transfer situations do not share any common elements, besides some specified response set. A classic example of this type of transfer is "learning to learn" situations (Postman, 1969).

A second distinction described by Royer is that of literal verses figural transfer. In literal transfer, and intact skill is directly used in the new learning situation. For example, you can directly apply knowledge of synaptic transmission to understand symptoms related to Parkinsons's disease. Figural transfer is described as a tool for learning in novel situations, and involves using some instance or unit of world knowledge to aid understanding. One common example is learning by analogy. For example, describing human information processing in terms of a computer.

A third and often-cited distinction used to describe transfer is that of near and far transfer. Near transfer, as originally defined by Mayer (1975), refers to a situation where both the original and new learning contexts are highly similar. An example of near transfer is learning to add two-digit numbers and assessing this skill with three-digit numbers. Far transfer is used to describe new learning situations that are "somewhat" different from the original learning context. Thus, being taught the skill of making change by an experimenter in a lab setting and subsequently using this skill when buying groceries in a store would constitute far transfer of the "making change" skill.

A fourth distinction compares vertical and lateral aspects of transfer and is based on Gagne's (1965) analysis of learning outcomes. The former he defined as use of a subordinate skill or skills when performing a superordinate skill. For example, the use of multiplication and subtraction skills when learning to divide. Lateral transfer refers to applying skills in one confined context (e.g., classroom) to some other, novel situations (e.g., real life). Thus, learning to calculate the area of a rectangle in school and using this knowledge to determine the size of a rug at home would constitute lateral transfer of this math skill. It should be noted that the notion of vertical transfer fits well with the objective-based training model (e.g., Gagne' & Briggs, 1979). Since vertical transfer describes a condition in which a subordinate skill is used when performing another, superordinate skill, the notion that two or more skills may be related in a hierarchical fashion becomes paramount to this view of transfer. Implications of vertical transfer for an objective-based training model will be outlined in the next section.

It is evident that there is much overlap between these four distinctions. In fact, differences that may exist between some of the distinctions may only be due to the examples used to describe them. For example, near and specific transfer appear only to differ in that specific transfer is related to the context of the learning environment (e.g., use of two different experimenters), and near transfer is described in terms of the stimulus features (e.g., use of three- instead of two-digit number). It should be noted that Royer (1979) glosses over this distinction by describing

his definition of near transfer as referring to "... one school-learned-event to another school-learned-event (p. 56)." This illustrates the need for researchers in the area to agree on some guidelines for evaluating training outcomes related to transfer of training effects. In this regard, Jacobs (1986) found evidence of inconsistent use of the terms near and far transfer by researchers when describing results of reading training studies (see e.g., Bauman, 1984; Short & Ryan, 1984, p. 233). In his discussion, Jacobs (1986) cautioned researchers within the training area to avoid such descriptive labels in this context unless their value to clearly communicate results has been established. This caution appears timely, since some researchers (Brown & Campione, 1984, p. 164) have suggested using yet another descriptive label (i.e., very far transfer) despite the apparent confusion surrounding the use of near and far. A similar posture has been adopted by some researchers in the area of clinical diagnosis due to the (continuing) controversy regarding the adoption and use of certain diagnostic labels (see e.g., Achenbach, 1980).

Implications of vertical transfer for an objective-based model of instruction

The skills necessary to perform an objective task and the relationships among these skills are identified by means of an instructional analysis. One widely used method of analysis, hierarchical analysis, is based on Robert Gagne's taxonomy, (Gagne', 1965, 1985; Gagne' & Briggs, 1979). Hierarchical analysis is used most frequently when the learning outcome is an intellectual skill. Using hierarchical analysis, intellectual skills identified as being part of a job task are broken down into those subordinate skills that are required by a given target population to achieve a terminal (or superordinate) objective. A hierarchical relation exists between skills if appropriate performance of one (subordinate) skill must necessarily predate the performance of another (superordinate) skill.

The relationship among skills is determined by asking the question: Is this skill needed in order to perform a higher-order skill? Another perspective is to take the higher-order skill and ask: What other skill, if not taught, would make performance of this superordinate skill impossible? Skills identified using these two procedures are thought to be hierarchical in nature. For example, to use spreadsheet functions one must be proficient with multiplication and division operations. To multiply and divide for this purpose one must be able to perform addition with carrying and subtraction with borrowing. Prerequisite to these skills are the ability to add without carrying and subtract without borrowing. The hierarchical nature of these skills is clear. Performance of the superordinate skill depends on adequate performance of the other, subordinate skill.

When used to assist trainees in learning complex job tasks, instructional theory dictates that an instructional analysis focusing on the types of required learning be performed. Job tasks associated with electricity and electronics tasks have hundreds of potential intellectual skills associated with them. Millions of dollars are spent each year in training electricians and

electronics technicians in the prerequisite skills necessary for the performance of higher-level technical tasks. A prerequisite objective that is, or should be, included in a learning analysis pertaining to electricity and electronics skill areas involves schematic symbols (cf., Cleaver, Meeusen, & Wells, 1966, p.V). Using Gagne' and Briggs' standard capability verb for a concrete concept, the trainee should be able to identify common schematic symbols.

Although the prerequisite objective of identifying schematic symbols is unquestionably an essential part of upper-level skills such as troubleshooting a complex electrical circuit, instruction rarely focuses on training these critical skills. In contrast, large amounts of time and resources are expended to help trainees identify various electrical circuits, which are configurations of schematic symbols.

Training aimed at facilitating identification of schematic symbols may focus on variable attributes of the to-be-learned concept, critical attributes needed for concept identification, or both sets of attributes. Particularly with coordinate concepts, learning the variable attributes of related concepts is important. Even so, some instructional research (Tennyson, 1978; Tennyson, Youngers, & Suebsonthi, 1983) suggests that trainees should first become exposed to a "best example" of each schematic symbol component. As an instructional design variable, a best example "represents an average, central, or prototypical form of a concept" (Tennyson & Cocchiarella, 1986, p.61). In the case of schematic symbols, such as diodes that are varied in shape, a best example should encode in memory a clear prototype that represents the more common dimensions of the concept class.

Methodology for Designing and Evaluating a Computer-Based ART Model

Primary task parameters

At the present time, a relatively simple discrimination task will be used as the primary task. This task involves having subjects listen to two sequentially presented tones (produced by the computer) and press one key if the second tone is higher in pitch than the first and another key if it is lower in pitch. The response mode of this task will be reversed on every other trial by having subjects discriminate between the tones according to whether or not the second tone is lower then the first tone. This is done in accordance with the varied mapping practice procedure described previously. Stimulus items for this task include several tones that can be easily discriminated from one another. Also, the tones are randomly produced so that on the average 50% are higher and 50% lower (for each set of 30 tones) than the one before it. At no time are two consecutive tones the same pitch. The presentation rate of the sets of tones will be adjustable from approximately one to five seconds. The latency between pairs of tones will be short (less than one second). We will use pilot data to identify the optimal number and the presentation rate of the tones. The computer will record and store accuracy and latency data for individual subjects for each trial (see below). In addition, task parameters involving rate of

presentation and latency between tones will be adjustable in order to vary the difficulty, and thus workload, of the primary task. In this way, we can increase or decrease concomitant attentional resources needed to perform the secondary task.

Secondary task parameters

The secondary task consists of 20 common electrical schematic symbols presented one at a time. These symbols are presented in Figure 2. A single trial will consist of individual responses to all 20 symbols. The computer randomly orders the symbols prior to each trial. For each symbol, subjects will be presented a single schematic symbol name. On the average, 90% of the name-symbol pairings will be correct. This rate was recommended by Schneider and Shiffrin in their 1977 articles. The subjects' task will be to identify whether or not the schematic name correctly matches the schematic symbol. A key-press response will be used for recording their answer. In addition, a variation of training for this task will involve rotation of individual symbols. Also, the keys used for both primary and secondary tasks will be arranged so that one hand responds to one task while the other hand responds to the other task. The program will be made flexible so that the subjects dominant hand will always respond to the secondary task and vice versa. This will allow us to use both primary and secondary tasks simultaneously and thereby utilize both procedures within a dual task training paradigm.

Insert Figure 2 about here

There are at least three criteria that may be employed for judging if processing demands related to the secondary task have been reduced as a result of training. First, the dual task procedure may be used to test attentional demands needed when performing the secondary task. Assessment in this context involves comparing secondary task performance (i.e., accuracy and latency data) in the presence of a competing task to baseline performance levels. Training can be considered complete if performance levels in each of these situations are approximately equal. Second, vocalization latency data can be collected involving digits and/or colors for individual subjects. These data can then be compared to vocalization latencies of schematic symbols. Thus, each subject will act as his or her own control. A third procedure can also be used for assessing training also involves vocalization latencies. That is, vocalization latencies of schematic symbols of subject matter experts (e.g., electrical engineers) can be collected and used as a standard for comparing latencies of subjects.

Transfer Task

The transfer task is an integral part of our experimental design, since a major goal of the ART model is to facilitate vertical

transfer effects above those found for mastery training alone. The transfer task we have chosen involves having subjects identify a novel simple circuit within larger schematic configurations. An example of a simple circuit is shown in Figure 3.

Insert Figure 3 about here

The configurations within which these circuits will be embedded will vary in their level of complexity. Examples of three levels of configuration complexity is shown in Figure 4. The design of the configurations is consistent with aspects of a Rational Set Generator (RSG) model developed by Driscoll and Tessmer (1985a, 1985b; see also Dempsey, 1986 describing adaptation of this model for use on the computer). For example, levels of complexity will be determined by varying such factors as (a) the total number of symbols in the configuration, (b) whether or not the symbols in the simple circuit are presented in the same sequence as when it is originally presented, (c) whether or not the simple circuit is rotated when imbedded in the configuration (relative to its original visual orientation), and (d) combinations of a, b, and c.

Insert Figure 4 about here

The basic procedure will involve presenting subjects with several simple circuits. After a brief (60 second) familiarization period, subjects will be asked to identify these circuits within a series of schematic configurations. Several examples will be given first, to familiarize them with this task. Configurations can then be presented on a computer and the subjects task is to touch the area of the configuration that incorporates a particular circuit. The subject will then be given a chance to identify the circuit by typing in some identifying code for that particular circuit. The computer will collect data on accuracy of responses (i.e., number of correct "hits" and errors of commission and omission) as well as time to correctly locate the circuits. Presentation of the configurations will be random and based on computer adaptation of the RSG model (Dempsey, 1986). In addition, presentation of the original simple circuits can be used as probes during the presentation sequence in order to directly test for memory of the simple circuits.

Traditional methodology for assessing ART model

Based on previous research (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977), one way to reduce attentional resources related to a skill is to use a constant mapping practice procedure. Using this procedure, one can reduce attentional resources related to the secondary task (described above) and then test the hypothesis that this type training facilitates vertical transfer. The superordinate skill in this case is recognition of

electrical circuits (described below). The procedure for testing this hypothesis is as follows:

(1) Provide initial (mastery) training to all subjects regarding identification of the 20 electrical symbols.

(2) Collect pretraining (baseline) data on both the primary and secondary tasks in terms of accuracy and response latencies. This can be done using the computer.

(3) Randomly assign half of the subjects to an ART condition using the constant mapping procedure. Assess reduction of attentional resources using a dual task procedure. Provide continued practice to the remaining subjects in order to control for general "practice" effects.

(4) Assess learning outcomes related to vertical transfer using all subjects.

Alternative methodology for assessing ART model

A second paradigm may also be used for examining aspects of vertical transfer using the dual task procedure as a training device. The procedure employing this alternative methodology is as follows:

(1) Provide (mastery) training to all subjects regarding identification of 20 electrical schematic symbols. Collect baseline vocalization latency data on naming digits and/or colors as well as for identification of 20 schematic symbols.

(2) Randomly assign half of the subjects to ART condition that utilizes dual task training as means to reduce attentional resources related to secondary task. For these subjects, training proceeds as follows: (a) assess pretraining (baseline) performance for both primary and secondary task, (b) primary task presented for short period to insure responding is similar to baseline levels, (c) secondary task added to primary task with instructions to subject to focus on performing primary task at original (baseline) levels, and (d) continue combined training until secondary task reaches baseline levels, making sure primary task performance remains constant. For other subjects, continue mastery training to control for potential practice effects. One variation of this design is to gradually increase primary task difficulty, thereby assessing the effects of variable levels of reduced attention with regard to vocalization latencies and vertical transfer for the secondary task.

(3) Assess effects of ART training by collecting vocalization latencies of 20 schematic symbols for all subjects. This will provide a direct comparison between ART model using dual task procedures and a discrete measure of automatic processing based on vocalization latency measures.

(4) Assess vertical transfer effects using all subjects.

Issues impeding application of the ART model for use in educational settings

There are several issues that must be empirically addressed before the ART model would be feasible for educational applications. These issues include the following:

(a) Incrementing task workload. That is, what is the best way to increase primary task workload? For some individuals, smaller increments would be optimal, but for others, larger increments may facilitate training. The deciding factor here may be the learner's response to failure. For example, if the learner becomes motivated in the face of wrong answer feedback, thereby increasing his or her performance on subsequent trials, then larger task workload increments may be used. If the learner tends to give up easily when their performance level is low, then smaller increments may be needed.

(b) Optimal primary task workload for producing durable attention reduction processing. In general, the ART model views attentional resources as being continuous in nature. Given that this training technique facilitates training and transfer in some meaningful way, there is a need to determine optimal levels of reduced attention for specific tasks and/or individuals.

(c) Use of multiple primary tasks. Providing a single competing task and varying specific task parameters (e.g., rate of tones or discriminability between tones) is only one way to increase task workload. Another possibility is to add more competing tasks, so that the learner must respond to each. This approach may be more realistic in the sense that in real-life situations, our attention is divided into several tasks simultaneously. For example, when reading, attention is given to individual word meanings, to literal comprehension of individual sentences, as well as to whether or not perceived meaning matches our knowledge and experience. However, in practice, setting up and monitoring several simultaneous tasks may not be feasible, if for not other reason, the mode of response of one task may interfere with encoding or responding to other tasks.

(d) Use of speeded training techniques for accomplishing attention reduction training. The reading literature has demonstrated the importance of speeded measures (e.g., recognition latency data) with respect to certain basic skills such as individual word recognition. Since researchers in this area have suggested that speed may be a critical component of automatic processing, there is a need to explore the relation between ART and training aimed at decreasing speed (e.g., repetitive reading). Results from such studies could be used to bolster the assumption that increases in speed may be attributed, in part, to a reduction in attentional resources. Conversely, it may be the case that automaticity is composed of two separable factors, reduced attention and increased speed. In either case, the results would be useful for designing and evaluating future models of training that view skill mastery as only one facet of efficient learning.

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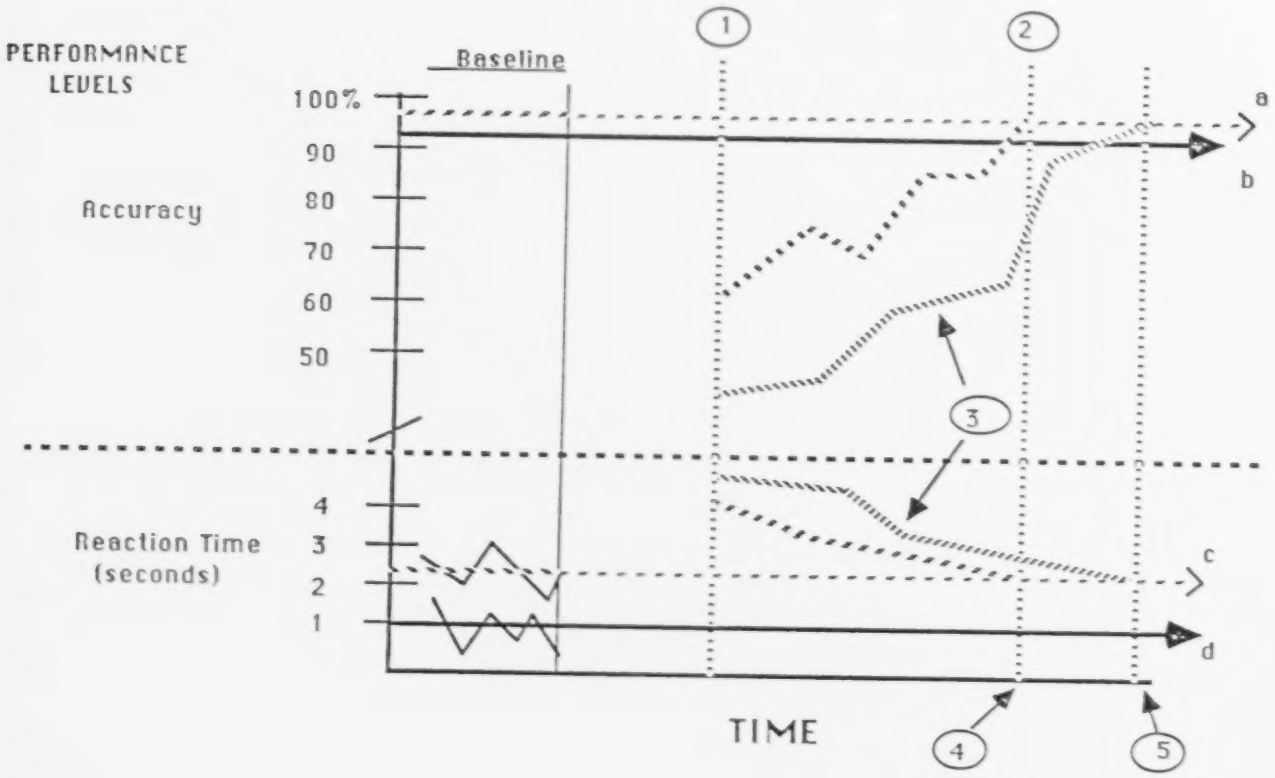
Primary task

Secondary task performance levels

Hypothesized secondary task performance levels with increased primary task workload used during dual task training



(1.) Dual task training begins now

(2.) Attention reduced via dual task training - automaticity thought to occur at this point in time

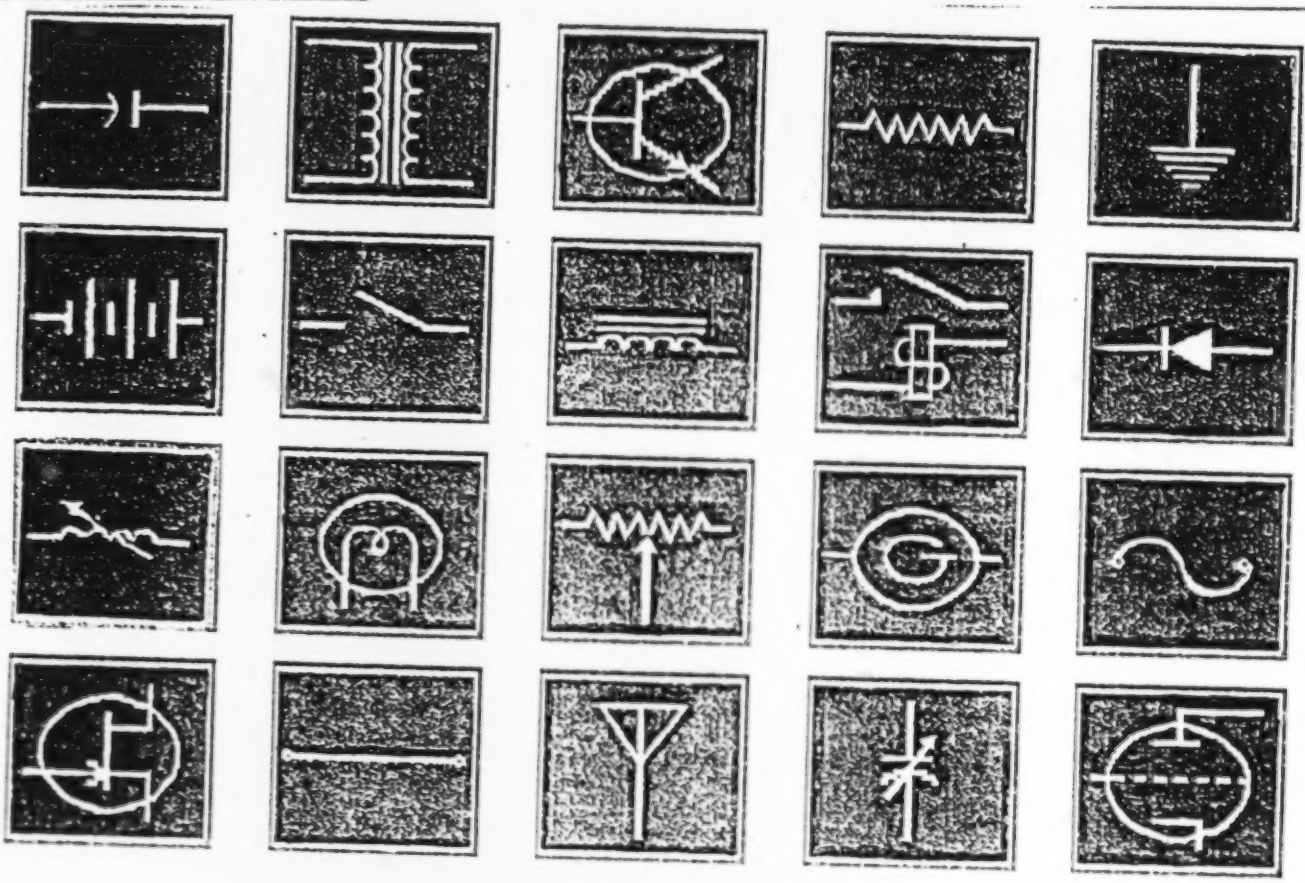
(3.) Hypothesized secondary task performance pattern when using primary task having greater cognitive workload

(4) & (5.) Assess voice latencies at points 4 & 5 as independent measure of amount of reduction of attentional resources

a thru d - Extended baselines for accuracy and RT performance levels

Figure 1

Primary and Secondary Task Performance Patterns Resulting from Attention Reduction Training Using Dual Task Technique



Row #1 (top): capacitor, transformer, transistor, resistor, ground

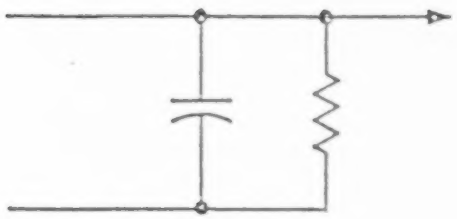
Row #2: battery, switch, inductor, relay, diode

Row #3: variable inductor, lamp, potentiometer, generator, fuse

Row #4: FET, conductor, antenna, variable capacitor, electron tube

Figure 2

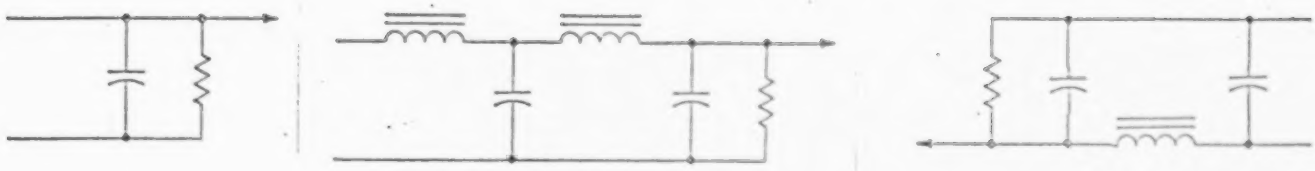
Common Electrical Schematics Used as
Secondary Task Stimuli for ART Study



single capacitor with bleeder

Figure 3

Example of Simple Circuit Used
in Transfer Task



single capacitor with bleeder

two section with choke input

rotated single capacitor with bleeder and input choke added

Level 1 (probe)

Level 2

Level 3

low

medium

high

Level of Comlexity

Figure 4

Example Schematic Configurations at Three Levels of Complexity for Use in Transfer Task